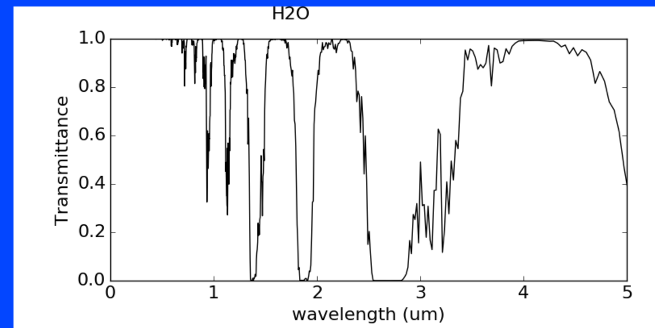
Broadband radiative transfer simulations for un-filtering process of radiances from CERES

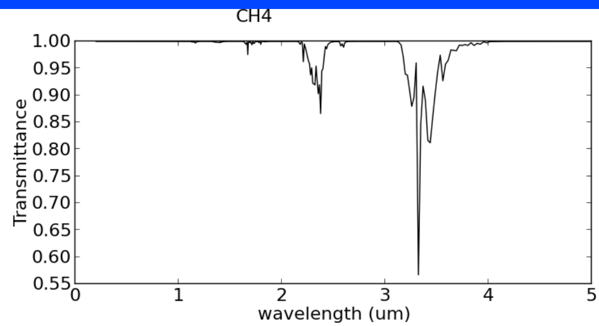
Lusheng Liang[1] and Wenying Su[2]

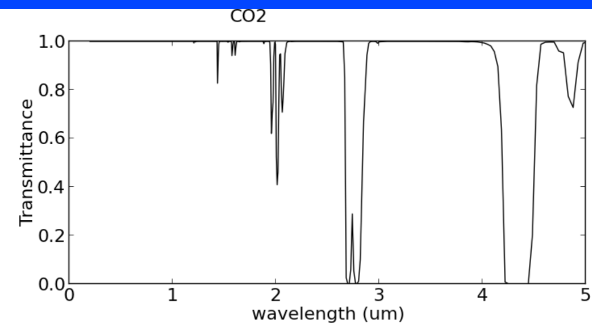
1-SSAI; 2-NASA LaRc

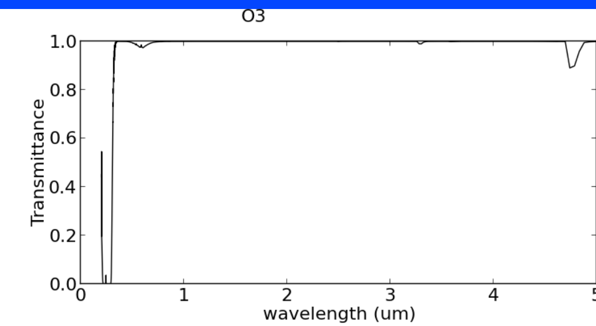
1. Absorption of atmospheric gases in shortwave

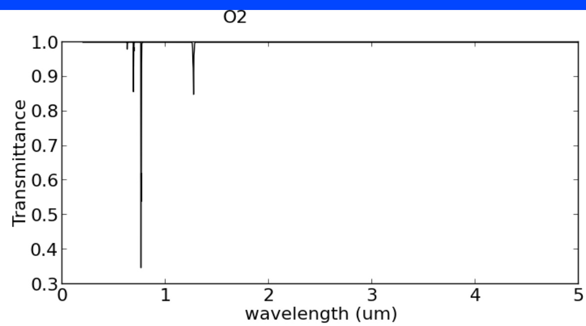
- Absorption properties of 7 major gases (H2O, O3, O2, CH4, CO2, CO and NO) in atmosphere are all derived from line parameter database (aer_v_3.2 based on HITRAN 2008) of LBLRTM code;
- The previous version of broadband radiative transfer code considered absorption properties of H2O, and O2 derived from LBLRTM line parameter database and the that of O3 was derived from WMO's Atmospheric Ozone 1985.

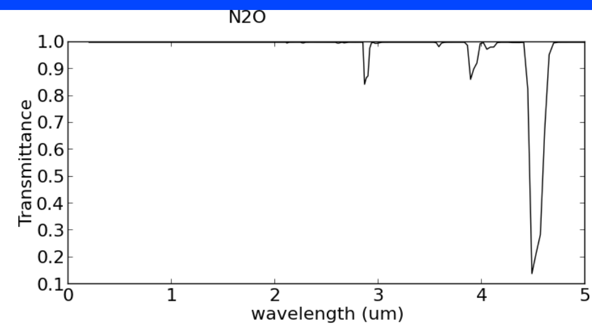


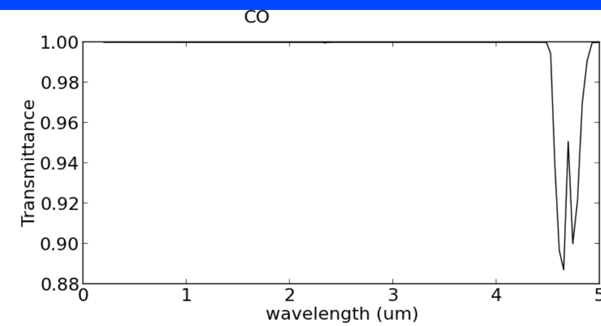






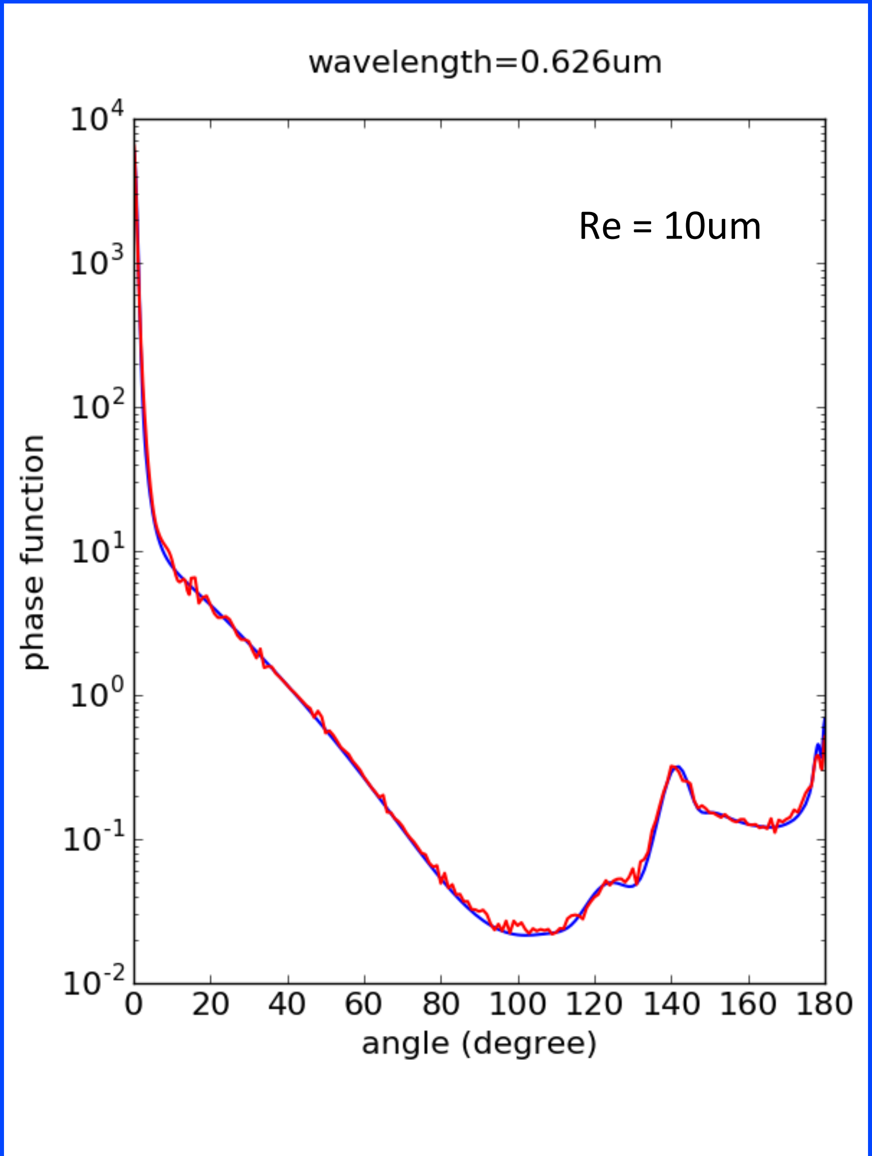






for the U.S. 1962 standard atmospheric profile

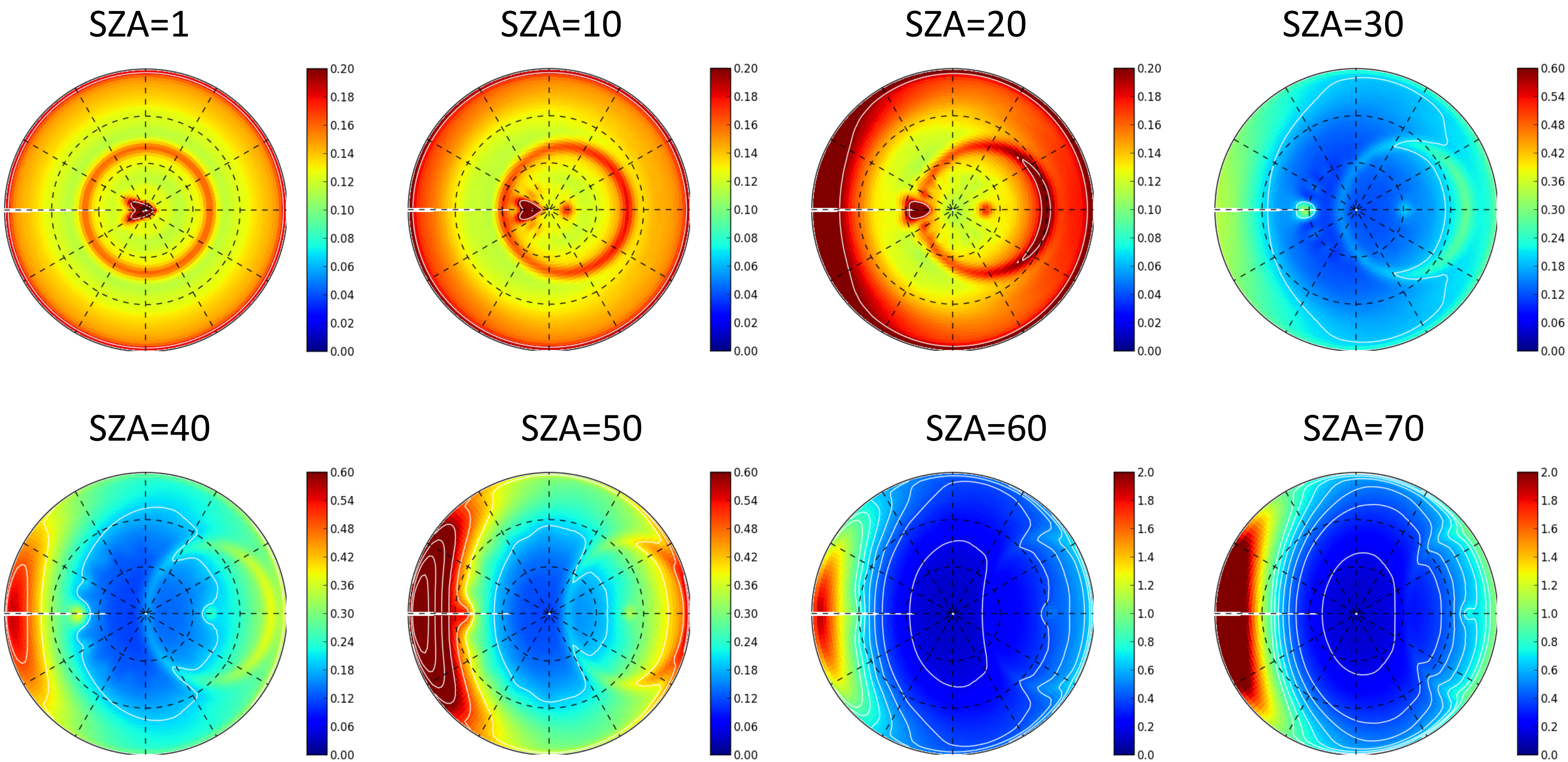
2.1 Cloud optical properties--water clouds



(1) Ping Yang's water cloud optical properties are used in the radiative transfer simulations

(2) Testing phase function (blue curve):
- log-normal distribution with the standard deviation of 0.35
- the range of the particle size distribution is from 0.001 um to 100 um with an interval of 0.001 um

BRF for water clouds based on the cloud optical properties



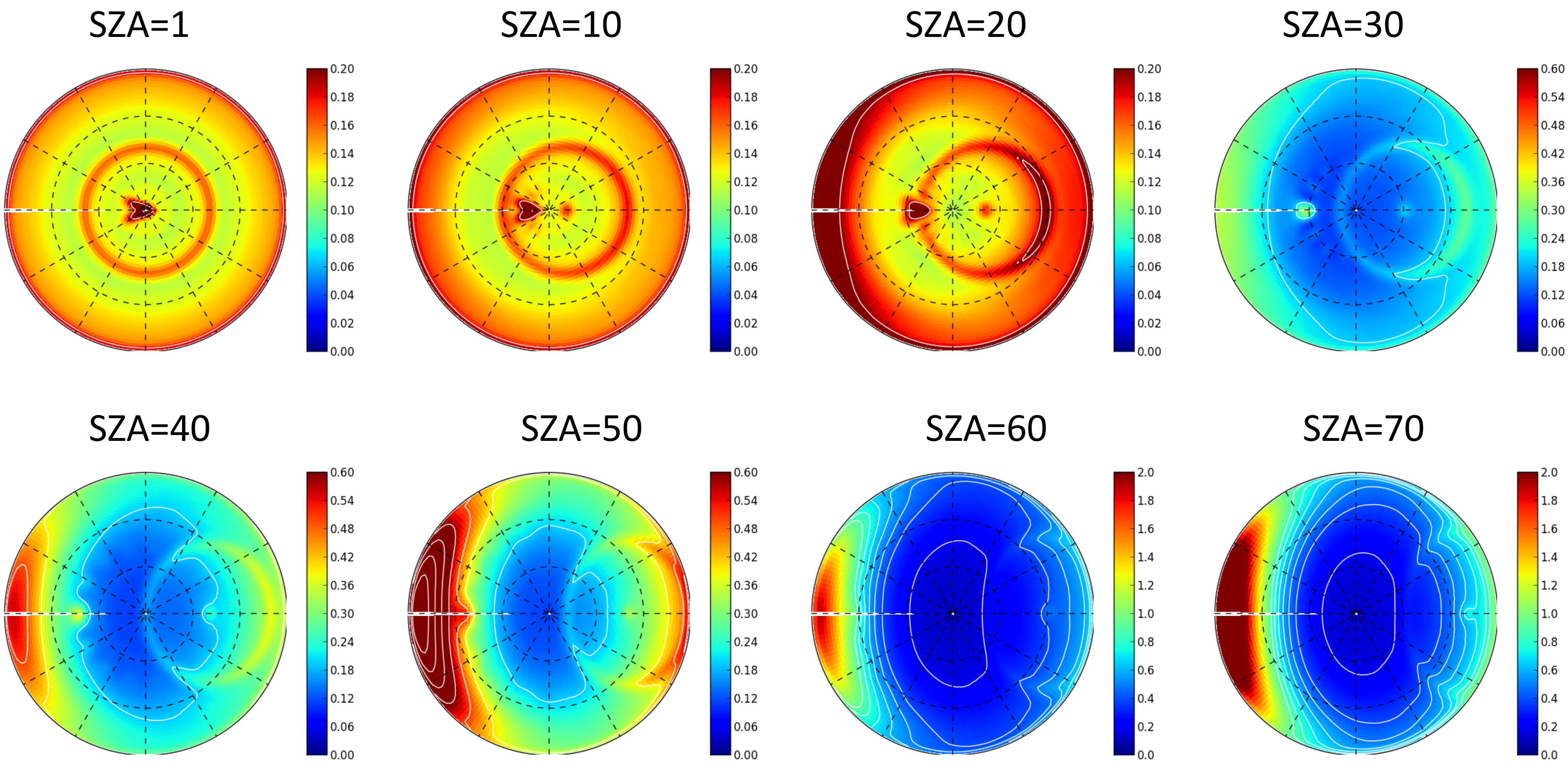
wavelength ranging from 0.626-0.714um
cloud optical depth=2
ocean surface wind speed=0 m/s
effective radius of clouds = 10um

2.2 Cloud optical properties—ice clouds

(1) The particle effective diameter is large relative to the wavelength in the shortwave;
(2) Very large peaks appear in the forward scattering directions close to 0 degree in the phase functions, which requires a lot of legendre polynomials to represent phase function in radiative transfer simulation and computations are too expensive;
(3) Phase functions need to be modified;
(4) Radiative transfer codes like DISORT are unable to produce the correct radiances with limited terms of legendre polynomials to represent phase function even with delta-M truncation is turned on for ice clouds.

Handling high peaks of ice cloud phase functions

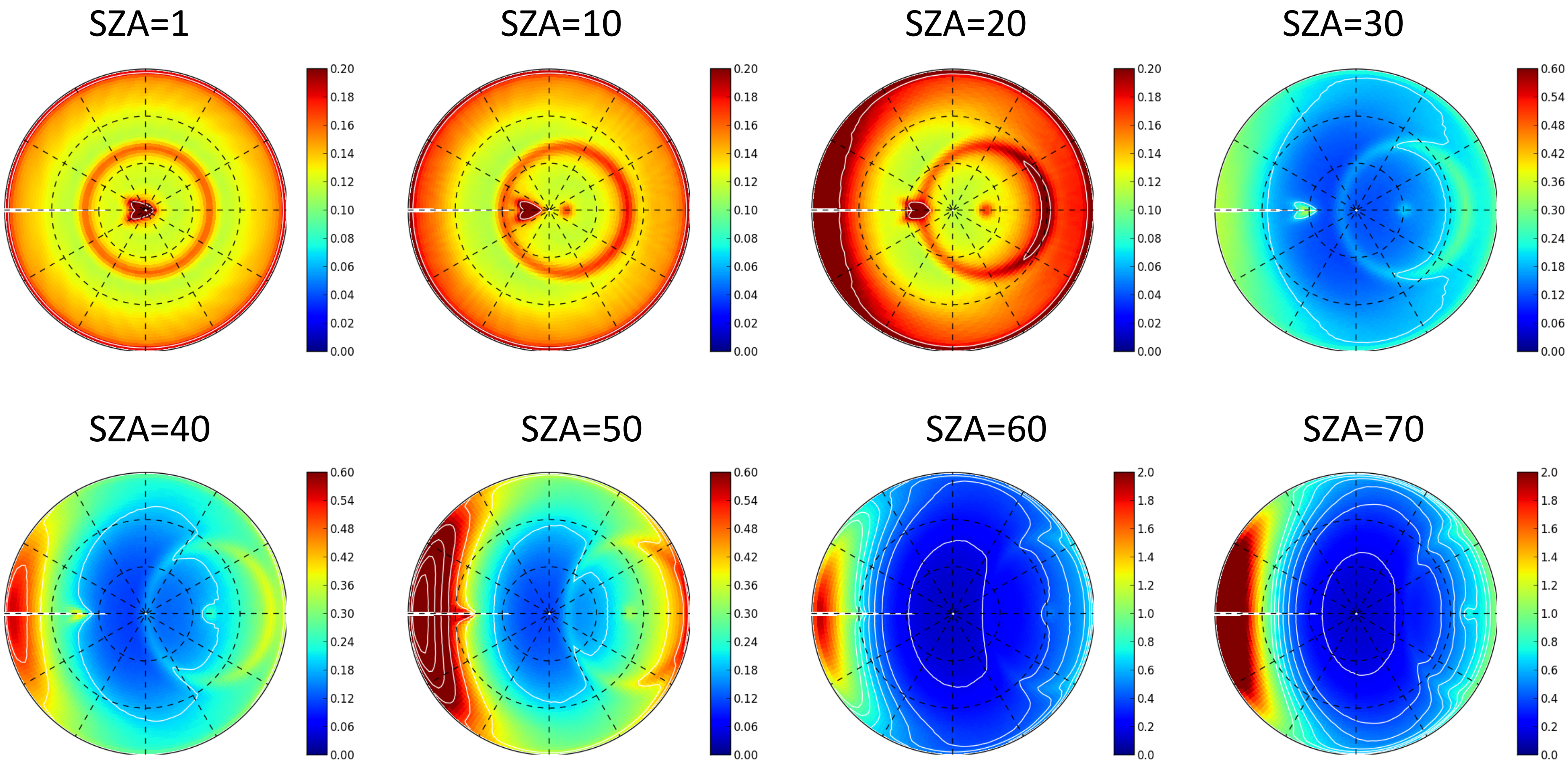
Reference BRF based on water cloud with Re=10um



wavelength ranging from 0.626-0.714um
water cloud optical depth=2
ocean surface wind speed=0 m/s
effective radius of clouds = 10um

Handling high peaks of ice cloud phase functions

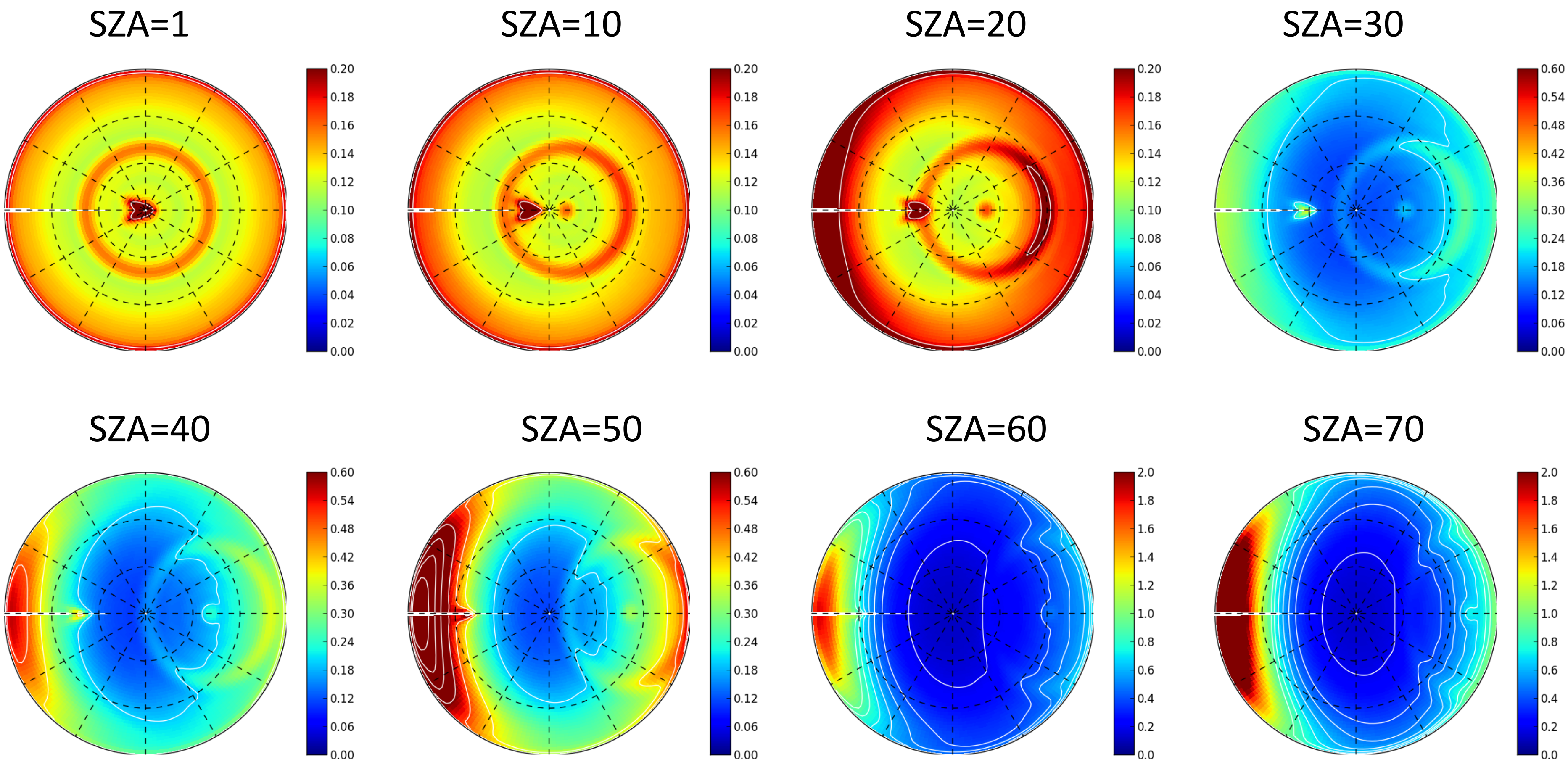
BRF calculated based on a geometry-cut algorithm (Iwabuchi and Suzuki, 2009)



wavelength ranging from 0.626-0.714um
water cloud optical depth=2
ocean surface wind speed=0 m/s
effective radius of clouds = 10um

Handling high peaks of ice cloud phase functions

BRF calculated based on the delta-fit algorithm (Hu et al., 2000)



wavelength ranging from 0.626-0.714um
water cloud optical depth=2
ocean surface wind speed=0 m/s
effective radius of clouds = 10um

3. Land surface Bidirectional Reflectance Distribution Functions

At a given wavelength, the BRF is calculated based on Ross-Li BRDF model

$$R = P_0 + P_1 K_1(\theta_0, \theta, \phi) + P_2 K_2(\theta_0, \theta, \phi)$$

where $K_1(\theta_0, \theta, \phi)$ and $K_2(\theta_0, \theta, \phi)$ are two kernels, and P_0, P_1 and P_2 are the BRDF parameters.

For every IGBP surface type:

- At wavelengths of MODIS 7 land bands (bands 1-7), BRDF parameters were averaged from MODIS 10-year observations (MCD43C1)
- The parameters at other wavelengths between 0.47 and 2.1um are calculated with spline interpolations
- The parameters at the wavelengths < 0.47 um or > 2.1 um are scaled along with the spectral reflectance from JPL spectral library 2.0.

4. Broad-band radiative transfer simulations over land

- Shortwave radiations are computed at a spectral resolution of $20cm^{-1}$ from 0.2 um to 5.0 um with a radiative transfer code based on DISORT.
- 16 streams for calculations containing water clouds or aerosols and 32 streams for calculations containing ice clouds.
- Broad-band radiative transfer simulations are performed for 7 IGBP surface types
  - 1: Evergreen Needleleaf Forest
  - 3: Deciduous Needleleaf Forest
  - 4: Deciduous Broadleaf Forest
  - 5: Mixed Forest
  - 10: Grasslands
  - 11: Permanent Wetlands
  - 16: Bare Soil and Rocks
- 6 bins of cosine of SZA (1.0, 0.85, 0.7, 0.55, 0.25, and 0.1)
- 9 bins of VZA (5, 15, 25, 35, 45, 55, 65, 75, and 85)
- 9 bins of RZA (5, 25, 45, 65, 85, 105, 125, 145, 165)
- 4 bins of aerosol optical depths (0, 0.05, 0.14 and 0.30, OPAC dust model for IGBP=16 and continental average aerosol model for other IGBP surface types)
- Ping Yang's water and ice cloud optical properties
- US 1976 standard atmosphere model

5. SW Radiance Unfiltering processes

1. Unfiltered, reflected radiance is calculated from filtered, reflected radiances as:

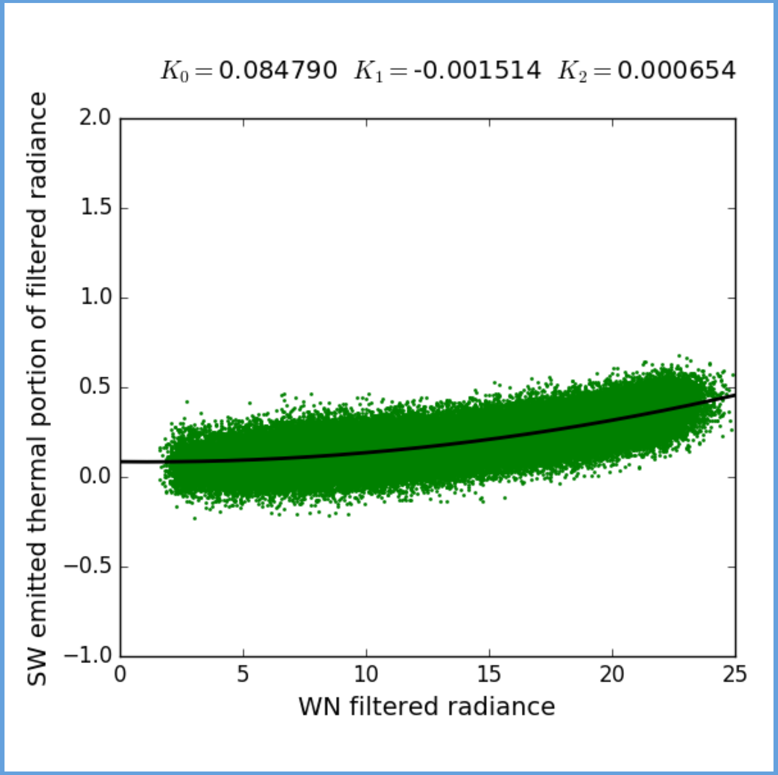
$$m_u^{sw} = a_0 + a_1(m_f^{sw_r}) + a_2(m_r^{sw_r})^2$$

2. The filtered, reflected radiance is calculated as:

$$m_f^{sw_r} = m_f^{sw} - m_f^{sw_e}$$

3. The emitted thermal portion of the filtered radiance is calculated as:

$$m_f^{sw_e} = K_0 + K_1(m_f^{wn}) + K_2(m_f^{wn})^2$$



The data are extracted from the first day in each month in 2001 of Ed4 night time Terra FM1.
Required SZA > 95 degrees to exclude the impact of twilight.

6. CERES SW radiance unfiltering coefficients as constructed from simulated reflected radiances

(1). Calculate unfiltered broadband radiances (no emitted)

$$m_u^{sw} = \int_0^\infty I_\lambda^r d\lambda$$

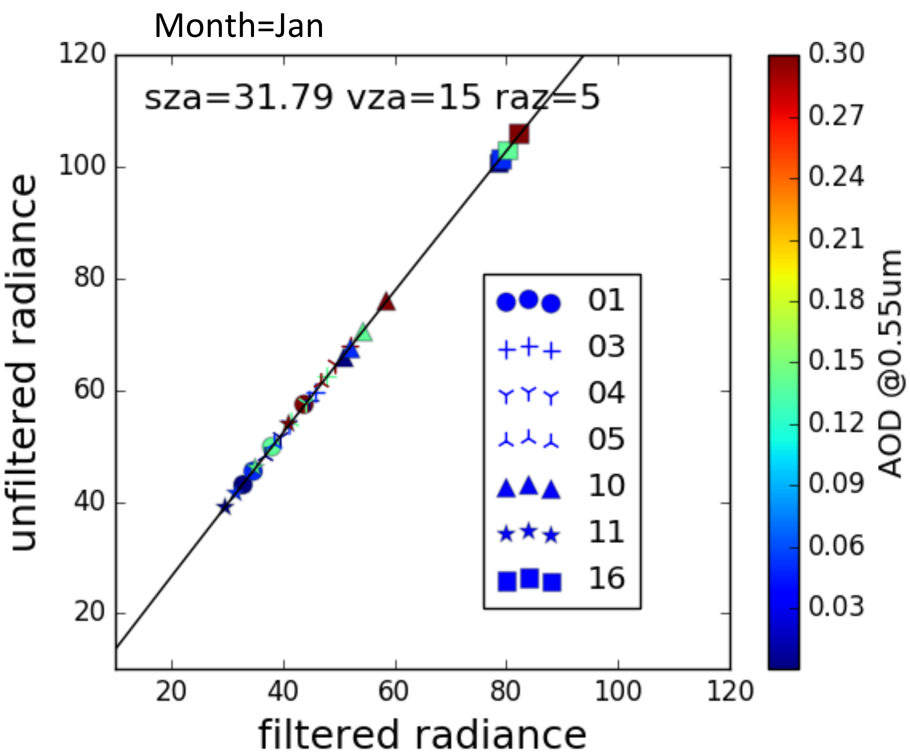
(2). Apply CERES spectral response functions to calculate filtered broadband radiances

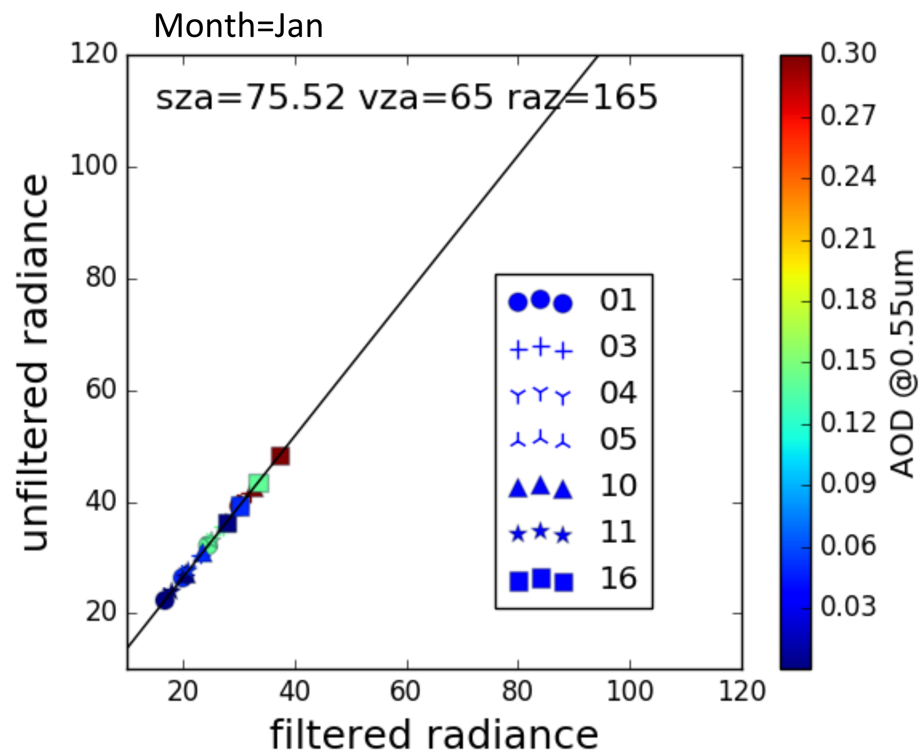
$$m_f^{sw} = \int_0^\infty S_\lambda^j I_\lambda^r d\lambda$$

(3). Convert filtered radiances to unfiltered radiances by

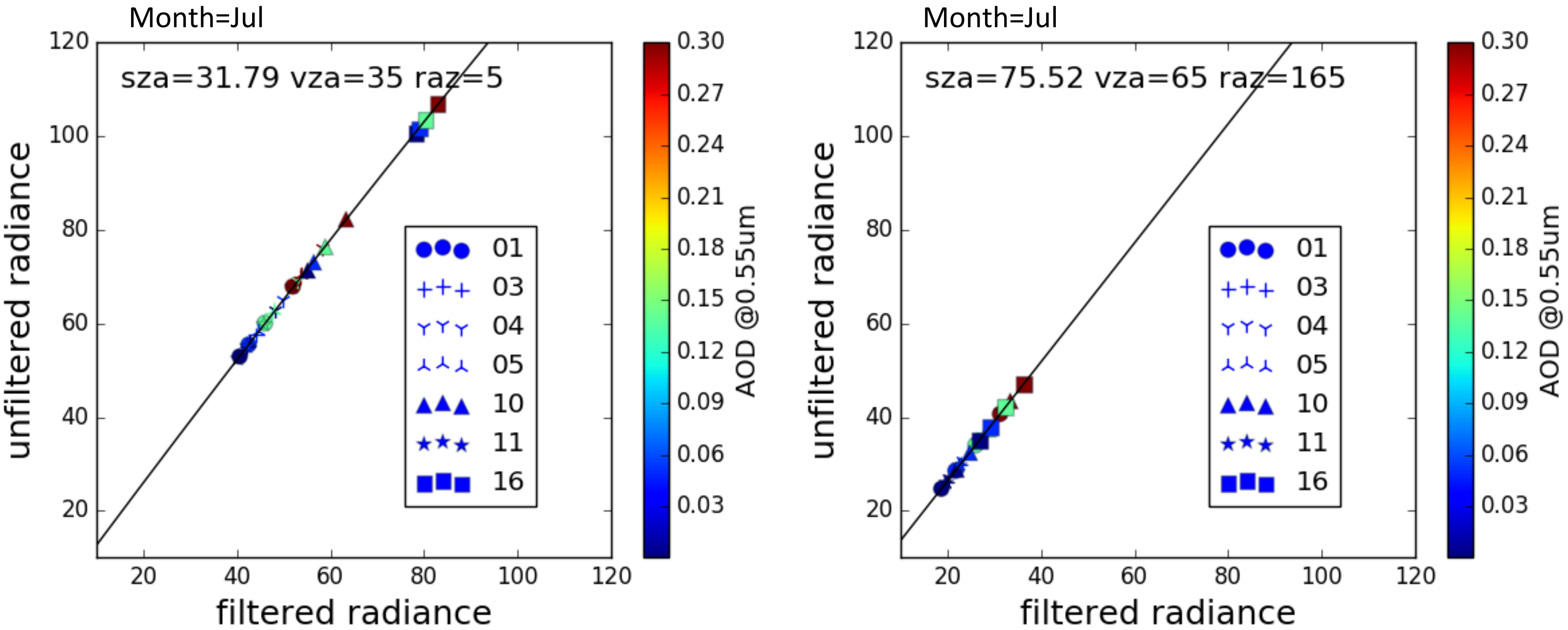
$$m_u^{sw} = a_0 + a_1(m_f^{sw_r}) + a_2(m_r^{sw_r})^2$$

(4). Calculate unfiltering coefficients (a_0, a_1 and a_2) in every SZA-VZA-RAZ bin. Within each bin, as for the currently available simulations, 28 pairs of data are used (7 IGBP types X 4 AOD).





The differences in coefficients (as shown in the fitting curve) between January and July are small.

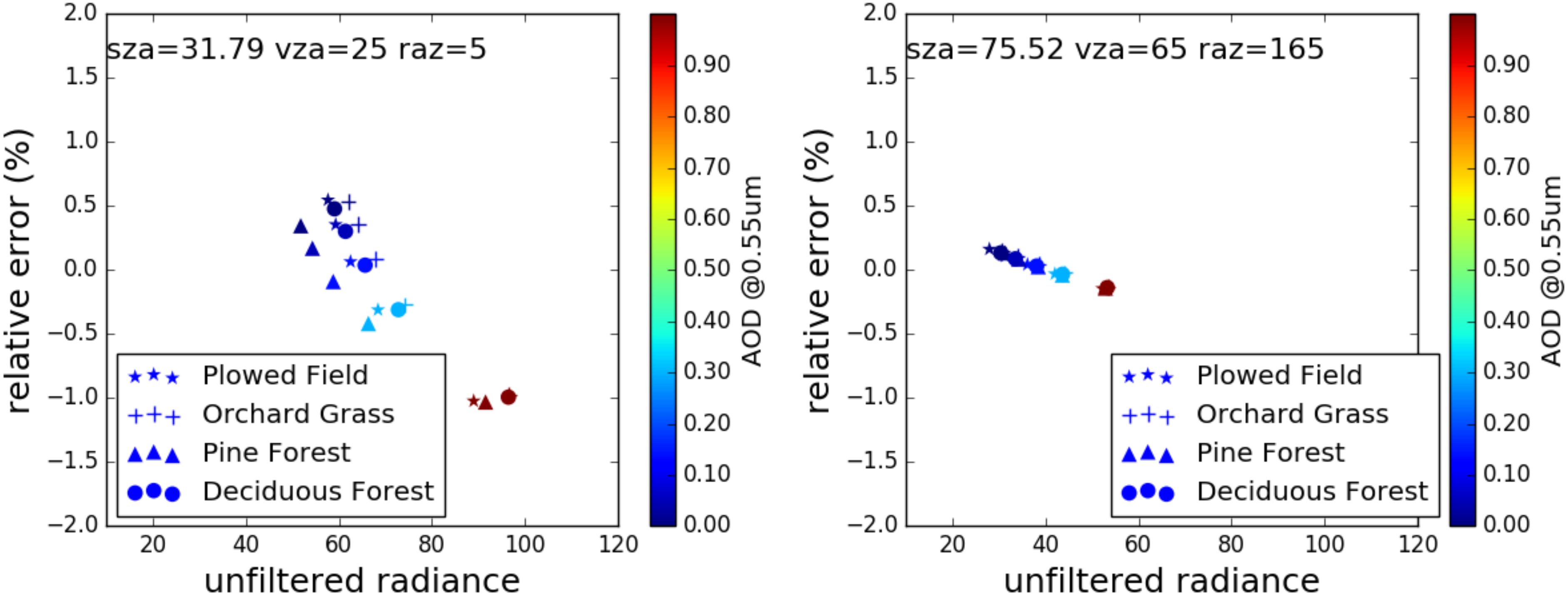


7. Errors in unfiltering processes over land

(1) Calculate broadband radiances (both filtered and unfiltered) with alternative BRDF models (Roujean et al, 1992). The surface models of plowed field, orchard grass, pine forest and deciduous forest are simulated; aerosol optical depths are 0, 0.05, 0.14, 0.30 and 1.0 of OPAC continental average model.

(2) Take the filtered radiances in (1) and apply unfiltering coefficients to get the unfiltered radiances.

(3) compare the unfiltered radiances in (2) to the unfiltered radiances in (1).



Future work

(1) Complete clear-sky unfiltering processes over land based on the simulations for all IGBP surface types
(2) Complete unfiltering processes for snow and sea ice
(3) Investigate the unfiltering processes for footprints partially covered by fresh snow or sea ice
(4) complete unfiltering processes over ocean
(5) Repeat (1) to (4) for cloudy conditions
(6) Repeat (1) to (5) in the longwave range